MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

ENT4066 – NANOELECTRONICS MATERIALS AND DEVICES

(NE)

09 February 2023
09:00 a.m. - 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) (i) Provide the definition for each of the terms in **Table Q1(a)** below:

Table Q1(a)

Term	Definition
Cluster	
Nanocrystal	
Nanocomposite	
Carbon nanotubes	

[4 marks]

(ii) Briefly explain "Quantum Confinement" phenomenon of nanocrystal and the reason why nanocrystals are referred to as Quantam dots (QDs) .

[2 marks]

(iii) Why does the melting point of the GOLD nanometer order particles decrease from that of the GOLD bulk materials? Explain the above statement with a simple graph.

[4 marks]

(b) (i) Energy bandgap of nanoparticle changes with the change of the particle size. Briefly explain how the energy bandgap of the nanoparticle differs from that of the bulk.

[4 marks]

(ii) What are the differences in "Exciton Bohr Radius" for a large semiconductor crystal and that of a quantum dot Nanomaterial?

[3 marks]

(c) (i) Explain the relation between the '***Gibbs Free Energy***' and the critical size of a homogenously nucleated nanoparticles.

[3 marks]

(ii) With aid of a diagram explain how under cooling results in formation of a large quantity of stable nuclei crystals.

[5 marks]

Continued.....

QUESTION 2

(a) Briefly describe the electron behaviour and optical emissions due to surface plasmonic effect of a metallic nanoparticle.

[3 marks]

(b) Besides surface plasmonics and exciton Bohr radius, which are other color generation mechanisms that can be induced by nanoparticles?

[3 marks]

(c) (15, 6) is a single-wall carbon nanotubes (SWCNT), The chiral angle (θ) and diameter (d) of a carbon nanotube (CNT) is given by:

$$\theta = tan^{-1}\left[\frac{\sqrt{3}\,n}{m+2n}\right]$$

$$d = \frac{\sqrt{3}\,a_{cc}\sqrt{(m^2+n^2+mn)}}{\pi}$$

respectively, where m and n are integers governing the chiral vector C, and a_{cc} = 0.142 nm is the carbon bond length. If unzipping the SWCNT form a 10-μm Graphene sheet,

(i) Calculate the chiral angle and diameter of the SWCNT.

[5 marks]

(ii) Is this a metallic or semiconductor type of CNT?

[1 mark]

(d) List **TWO (2)** mechanical properties of CNT and provide example CNT application that utilized the mechanical properties.

[4 marks]

(e) Draw a diagram that show the influence of time on the growth of monodispersed colloid.

[4 marks]

Continued.....

(f) **Figure Q2(f)** shows Density-of-states D(E) with van- Hove singularities for (3,3), (5,5) and (10,10) armchair nanowire with N=3,600 is the number of the atoms. Explain Van Hove Singularities" based on the **Figure Q2(f)**.

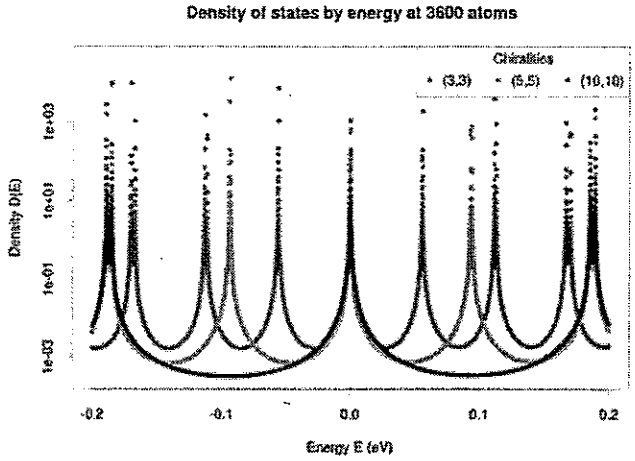

Figure Q2(f)

[5 marks]

Continued.....

QUESTION 3

(a) Differentiate the three scaling rules; *constant field scaling*, *generalized scaling* and *generalized selective scaling*, of metal-oxide-semiconductor field-effect transistor (MOSFET). Explain the significance of such scaling rules.

[3 marks]

(b) Arc discharge is a high temperature dependent method used to fabricate carbon nano tube (CNT). With the aid of a suitable diagram, write a short note about the fabrication process of CNT using "Arc discharge" method.

[2+4 marks]

(c) (i) Single-electron transistor (SET) is consider as a state of the art nanoelectronic device where a quantum dot is weakly coupled between two thin metallic drain and source. Sketch the equivalent circuit that represent a SET device.

[3 marks]

(ii) What are the **TWO** (2) important criteria that govern the SET operation?

[2 marks]

(iii) Derive that the threshold V_{th} is given by e/C_{tot}, where C_{tot} is the total capacitance.

[3 marks]

(d) What are the **THREE** (3) variant of Silicon on Insulator (SOI) devices? Compare their strengths and weaknesses.

[6 marks]

(e) What would be the scaling issues of very thin SiO_2 if chip manufacturers shrunken the thickness of the to as little as five atomic layers (1.2 nm)?

[3 marks]

Continued...

QUESTION 4

(a) Resonant Tunneling Diodes (RTDs) with negative differential resistance (NDR) characteristics, have the potential to improve the circuit performance by combining conventional devices.

(i) Explain why RTD are very attractive in improving device performance.
[3 marks]

(ii) With the aid of a diagram that represents differential resistance (NDR).
[2 marks]

(iii) The capacitance of a nanosized island used in a single-electron transistor (SET) Is given by $C=2\pi\varepsilon\varepsilon_o d$, where d (12 nm) is the diameter of island, $\varepsilon=4$ and $\varepsilon_o = 8.89\text{x}10^{-12}$ F/m. Calculate the temperature limit for SET effect. Given that Boltzmann's constant is $1.38066\text{x}10^{-23}$ J/K.
[3 marks]

(b) Single electron transistor (SET) devices are expected to bring a revolution in the electronic devices. With the aid of a diagram illustrate the different regime of a SET devices and explain the operational principles of the SET devices.
[5 marks]

(c) Describe the working principle of the SET devices if they are used in the following applications:
(i) Single electron memory
(ii) High sensitivity electrometer
(iii) Microwave detection
[3 marks]

(d) (i) Sketch the energy level diagram that illustrating the quantum-dot light-emitting diode (QD-LED), and explain how the QD-LED works.
[3+4 marks]

(ii) Explain briefly how luminescence colour can be tuned over the entire visible wavelength range in QD-LED.
[2 marks]

End of Paper